CHAPTER 1

Introduction to Chemistry

What You'll Learn

- You will describe the relationship between chemistry and matter.
- You will recognize how scientific methods can be used to solve problems.
- You will distinguish between scientific research and technology.

Why It's Important

- You, and all the objects around you, are composed of matter. By studying matter and the way it changes, you will gain an understanding of your body and all the "stuff" you see and interact with in your everyday life.

CLICK HERE

CHEMISTRY Online

Visit the Chemistry Web site at **science.glencoe.com** to find links about chemistry and matter.

The four nebulae shown here contain a stew of elements. The red color in two of the nebulae is emitted by hydrogen atoms. The Horsehead Nebula can be seen on the right. The fourth nebula is the bluish structure below the horse's head. The round, bright object on the left is the star, Zeta Orionis.

DISCOVERY LAB

Materials

large kitchen matches
laboratory balance
lab notebook
pen
stopwatch or clock

Where is it?

When an object burns, the quantity of ashes that remain is smaller than the original object that was burned. What happened to the rest of the object?

Safety Precautions

Do not place matches in the sink. Use caution around flames.

Procedure

1. Measure the mass of a large kitchen match. Record this measurement and detailed observations about the match.
2. Carefully strike the match and allow it to burn for five seconds. Then, blow it out. CAUTION: *Keep hair and loose clothing away from the flame.* Record observations about the match as it burns and after the flame is extinguished.
3. Allow the match to cool. Measure and record the mass of the burned match.
4. Place the burned match in a container designated by your instructor.
5. Repeat this procedure. Compare your data from the two trials.

Analysis

How do you account for the change in mass? Where is the matter that appears to have been lost?

Section 1.1 The Stories of Two Chemicals

Objectives

- **Explain** the formation and importance of ozone.
- **Describe** the development of chlorofluorocarbons.

Take a moment to look around you. Where did all the “stuff” you see come from? All the stuff in the universe is made from building blocks formed in stars such as the ones shown in the photo on the opposite page. And, as you learned in the **DISCOVERY LAB,** this stuff changes form.

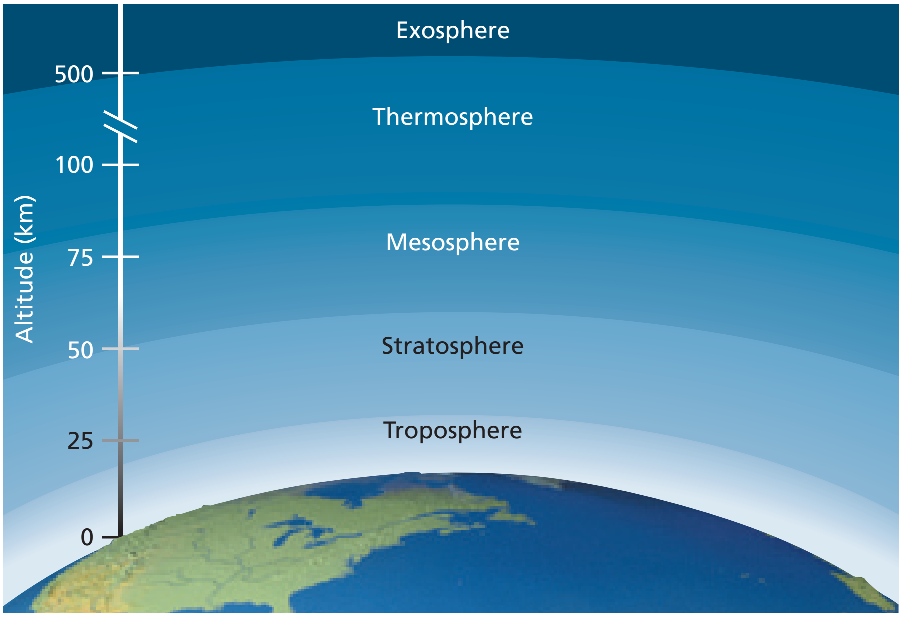
Scientists are naturally curious. They continually ask questions about and seek answers to all that they observe in the universe. One of the areas in which scientists work is the branch of science called chemistry. Your introduction to chemistry will begin with two unrelated discoveries that now form the basis of one of the most important environmental issues of our time.

The Ozone Layer

You are probably aware of some of the damaging effects of ultraviolet radiation from the Sun if you have ever suffered from a sunburn. Overexposure to ultraviolet radiation also is harmful to plants and animals, lowering crop yields and disrupting food chains. Living things can exist on Earth because ozone, a chemical in Earth’s atmosphere, absorbs most of this radiation before it reaches Earth’s surface. A chemical is any substance that has a definite composition. Ozone is a substance that consists of three particles of oxygen.

Figure 1-1

Earth's atmosphere consists of several layers. The layer nearest Earth is the troposphere. The stratosphere is above the troposphere.



Earth's atmosphere As you can see in **Figure 1-1,** Earth's atmosphere consists of layers. The lowest layer is called the troposphere and contains the air we breathe. The troposphere is where the clouds shown in **Figure 1-2** occur and where airplanes fly. All of Earth's weather occurs in the troposphere.

The stratosphere is the layer above the troposphere. It extends from about 15 to 50 kilometers (km) above Earth's surface. The ozone that protects Earth is located in the stratosphere. About 90% of Earth's ozone is spread out in a layer that surrounds and protects our planet.

Ozone formation How does ozone enter the stratosphere? Ozone is formed when oxygen gas is exposed to ultraviolet radiation in the upper regions of the stratosphere. Particles of oxygen gas are made of two smaller oxygen particles. The energy of the radiation breaks the gas particles into oxygen particles, which then interact with oxygen gas to form ozone. **Figure 1-3** illustrates this process. Ozone also can absorb radiation and break apart to reform oxygen gas. Thus, there tends to be a balance between oxygen gas and ozone levels in the stratosphere.

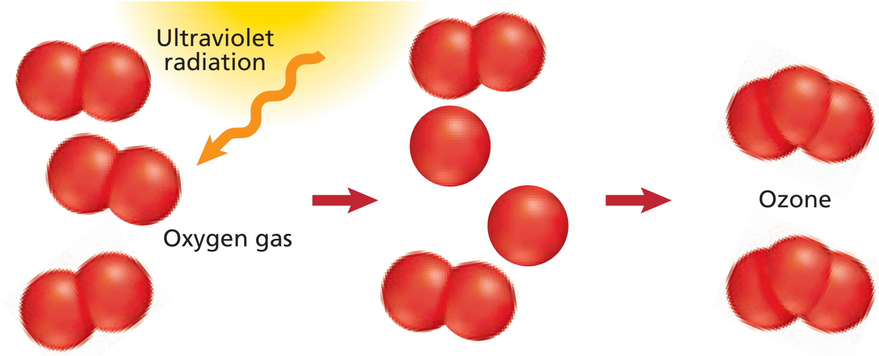
Ozone was first identified and measured in the late 1800s, so its presence has been studied for a long time. It was of interest to scientists because air currents in the stratosphere move ozone around Earth. Ozone forms over the equator where the rays of sunlight are the strongest and then flows toward the poles. Thus, ozone makes a convenient marker to follow the flow of air in the stratosphere.

In the 1920s, G.M.B. Dobson began measuring the amount of ozone in the atmosphere. Although ozone is formed in the higher regions of the stratosphere, most of it is stored in the lower stratosphere, where it can be measured by instruments on the ground or in balloons, satellites, and rockets. Dobson measured levels of stratospheric ozone of more than 300 Dobson units (DU). His measurements serve as a basis for comparison with recent measurements.

During 1981–1983, a research group from the British Antarctic Survey was monitoring the atmosphere above Antarctica. They measured surprisingly low levels of ozone, readings as low as 160 DU, especially during the Antarctic spring in October. They checked their instruments and repeated their measurements. In October 1985, they reported a confirmed decrease in the amount of ozone in the stratosphere and concluded that the ozone layer was thinning.

Figure 1-2

The troposphere extends to a height of about 15 km. Cumulonimbus clouds, or thunderheads, produce thunder, lightning, and rain.



Formation of ozone

Figure 1-3

This model of the formation of ozone shows that ultraviolet radiation from the Sun causes oxygen gas to break down into two individual particles of oxygen. These individual oxygen particles combine with oxygen gas to form ozone, which consists of three oxygen particles.

Although the thinning of the ozone layer is often called the ozone hole, it is not actually a hole. You can think of it as being similar to the old sock in **Figure 1-4a** in which the material of the heel is wearing thin. You might be able to see your skin through the thinning sock. So although the ozone is still present in the atmosphere, the protective layer is much thinner than normal. This fact has alarmed scientists who never expected to find such low levels. Measurements made from balloons, high-altitude planes, and satellites have supported the measurements made from the ground, as the satellite map in **Figure 1-4b** shows. What could be causing the ozone hole?

CHEMISTRY CD-ROM

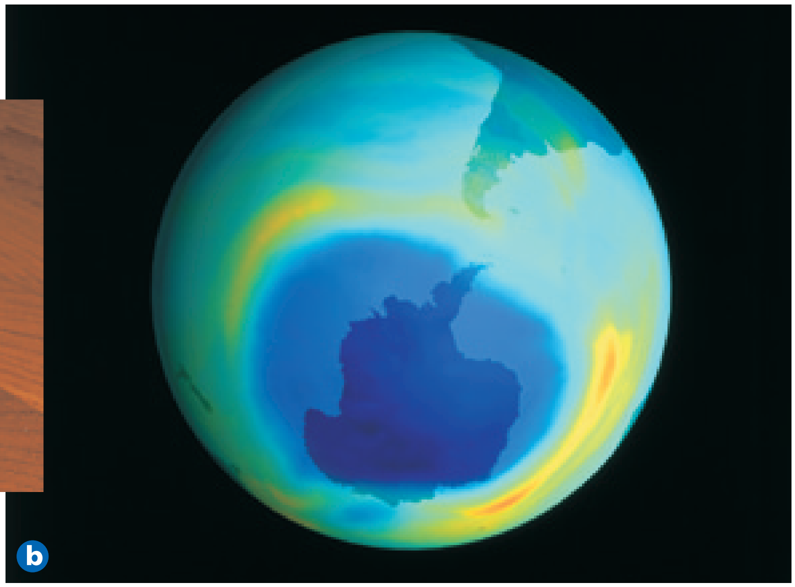
Go to the **Chemistry Interactive CD-ROM** to find additional resources for this chapter.

Chlorofluorocarbons

The story of the second chemical in this chapter begins in the 1920s. Refrigerators, which used toxic gases such as ammonia as coolants, were just beginning to be produced large scale. Because ammonia fumes could escape from the refrigerator and harm the members of a household, chemists began to search for safer coolants. Thomas Midgley, Jr. synthesized the first chlorofluorocarbons in 1928. A chlorofluorocarbon (CFC) is a chemical that consists of chlorine, fluorine, and carbon. There are several different chemicals that are classified as CFCs. They are all made in the laboratory and do not occur naturally. CFCs are nontoxic and stable. They do not readily react with other chemicals. At the time, they seemed to be ideal coolants for refrigerators. By 1935, the first self-contained home air-conditioning units and eight million new refrigerators in the United States used CFCs as coolants. In addition to their use as refrigerants, CFCs also were used in plastic foams and as propellants in spray cans.

Figure 1-4

a The thinning heel of this sock models the thinning of the ozone layer in the stratosphere. **b** This colored satellite map of stratospheric ozone over Antarctica was taken on September 15, 1999. The lowest amount of ozone (light purple) appears over Antarctica (dark purple). Blue, green, orange, and yellow show increasing amounts of ozone.



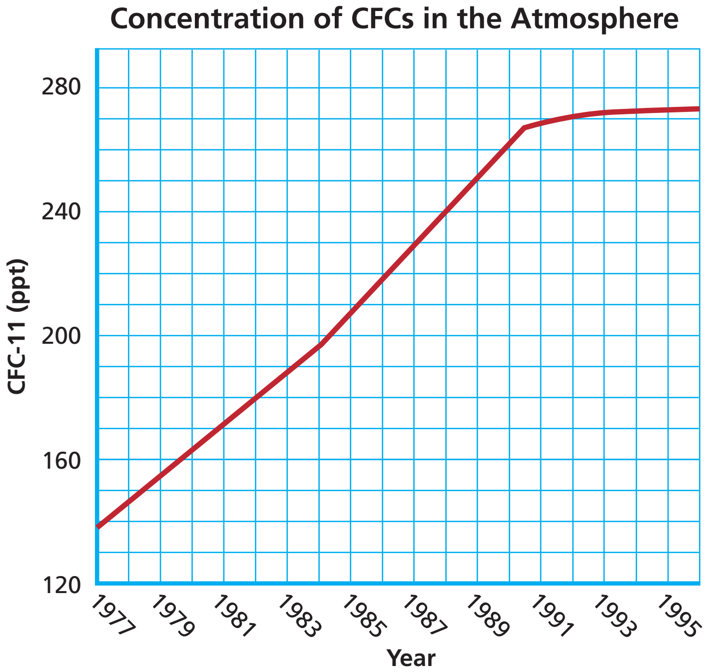


Figure 1-5

Quantities of CFCs in the atmosphere continued to rise until a ban on products containing them went into effect in many countries.

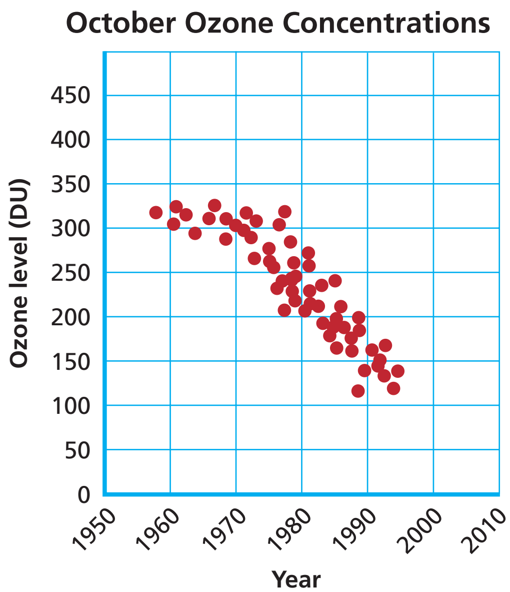
Now think of all the refrigerators in your neighborhood, in your city, across the country, and around the world. Think of the air conditioners in homes, schools, office buildings, and cars that also used CFCs. Add to your mental list all of the aerosol cans and plastic foam cups and food containers used each day throughout the world. If all of these products contained or were made with CFCs, imagine the quantities of these chemicals that could be released into the environment in a single day.

Scientists first began to notice the presence of CFCs in the atmosphere in the 1970s. They decided to measure the amount of CFCs in the stratosphere and found that quantities in the stratosphere increased year after year. This increase is shown in **Figure 1-5.** But, it was thought that CFCs did not pose a threat to the environment because they are so stable.

Two separate occurrences had been noticed and measured: the protective ozone layer in the atmosphere was thinning, and increasingly large quantities of useful CFCs were drifting into the atmosphere. Could there be a connection between the two occurrences? Before you learn the answer to this question, you need to understand some of the basic ideas of chemistry and know how chemists—and most scientists, for that matter—solve problems.

Section 1.1 Assessment

1. Why is ozone important in the atmosphere?
2. Where is ozone formed and stored?
3. What are CFCs? How are they used?
4. **Thinking Critically** Why do you think ozone is formed over the equator? What is the connection between sunlight and ozone formation?
5. **Comparing and Contrasting** What general trend in ozone concentration is shown in the graph at the right? How does the data for the years 1977–1987 on this graph compare to the same time span on the graph in **Figure 1-5?** What do you notice?



Section 1.2 Chemistry and Matter

Matter, the stuff of the universe, has many different forms. You are made of matter. There is matter in the bed, blankets, and sheets on which you sleep as well as in the clothes you wear. There is matter in the food you eat, and in medications and vitamins you may take. You have learned that ozone is a chemical that occurs naturally in the environment, whereas CFCs do not. Although both chemicals are invisible gases, they, too, are matter.

Objectives

- **Define** chemistry and matter.
- **Compare** and **contrast** mass and weight.
- **Explain** why chemists are interested in a submicroscopic description of matter.

Vocabulary

chemistry
matter
mass
weight

Chemistry: The Central Science

Chemistry is the study of matter and the changes that it undergoes. A basic understanding of chemistry is central to all sciences—biology, physics, Earth science, ecology, and others. Chemistry also is central to our everyday lives, as **Figure 1-6** illustrates. It will continue to be central to discoveries made in science and technology in the twenty-first century.

Figure 1-6

High-tech fabrics that don't hinder athletic performance, water, fertilizers, pesticides, food, grocery items, clothing, building materials, hair care products, plastics, and even the human body are made of chemicals.

Figure 1-7

A scale measures the downward pull of gravity on an object. If this scale were used on the Moon, the reading would be less than on Earth.

Matter and its Characteristics

You recognize matter in the everyday objects you are familiar with, such as those shown in **Figure 1-6.** But, how do you define matter? **Matter** is anything that has mass and takes up space. **Mass** is a measurement that reflects the amount of matter. It is easy to see that your textbook has mass and takes up space. Is air matter? You can't see it and you can't always feel it. However, when you inflate a balloon, it expands to make room for the air. The balloon gets heavier. Thus, air must be matter. Is everything made of matter? The thoughts and ideas that "fill" your head are not matter; neither are heat, light, radio waves, nor magnetic fields. What else can you name that is not matter?

Mass and weight When you go to the supermarket to buy a pound of vegetables, you place them on a scale like the one shown in **Figure 1-7** to find their weight. **Weight** is a measure not only of the amount of matter but also of the effect of Earth's gravitational pull on that matter. This force is not exactly the same everywhere on Earth and actually becomes less as you move away from Earth's surface at sea level. You may not notice a difference in the weight of a pound of vegetables from one place to another, but subtle differences do exist.

It might seem more convenient for scientists to simply use weight instead of mass. You might wonder why it is so important to think of matter in terms of mass. Scientists need to be able to compare the measurements that they make in different parts of the world. They could identify the gravitational force every time they weigh something but that is not practical or convenient. This is why they use mass as a way to measure matter independent of gravitational force.

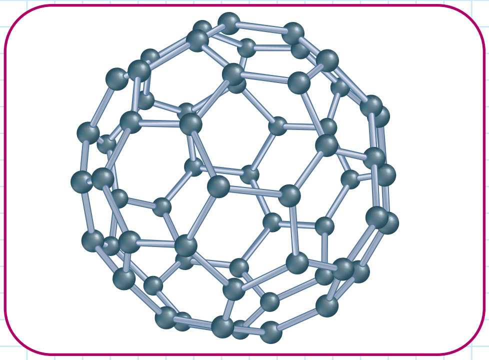
What you see and what you don't What can you observe about the outside of your school building or a skyscraper downtown? You know that there is more than meets the eye to such a building. There are beams inside the walls that give the building structure, stability, and function. Consider another

problem-solving LAB

Chemical Models

Making Models Until the mid-1980s, scientists thought there were only two forms of carbon, each with a unique structure: diamond and graphite. As with many scientific discoveries, another form of carbon came as a surprise.

Buckminsterfullerene, also called the buckyball, was found while researching interstellar matter. Scientists worked with various models of carbon structures until they determined that 60 carbons were most stable when joined together in a shape that resembles a soccer ball.



Analysis

Examine the structure in the diagram. Where are the carbon atoms? How many carbons is each carbon connected to? Identify the pentagons and hexagons on the faces on the buckyball.

Thinking Critically

Go back to **Figure 1-3** to see an example of another model that chemists use. What process does the figure show? Explain why this information could not be shown in a photograph. What do the colored particles represent? Use **Table C-1** in Appendix C to help you in your identification.

Table 1-1

Branches of Chemistry		
Branch	**Area of emphasis**	**Examples**
Organic chemistry	Most carbon-containing chemicals	Pharmaceuticals, plastics
Inorganic chemistry	In general, matter that does not contain carbon	Minerals, metals and nonmetals, semiconductors
Physical chemistry	The behavior and changes of matter and the related energy changes	Reaction rates, reaction mechanisms
Analytical chemistry	Components and composition of substances	Food nutrients, quality control
Biochemistry	Matter and processes of living organisms	Metabolism, fermentation

example. When you bend your arm at the elbow, you observe that your hand comes toward your shoulder. Muscles that you cannot see under the skin contract and relax to move your arm.

Much of matter and its behavior is macroscopic; that is, you do not need a microscope to see it. You will learn in Chapter 3 that the tremendous variety of stuff around you can be broken down into more than 100 types of matter called elements, and that elements are made up of particles called atoms. Atoms are so tiny that they cannot be seen even with optical microscopes. Thus, atoms are *sub*microscopic. They are so small that 100 million million million atoms could fit onto the period at the end of this sentence.

The structure, composition, and behavior of all matter can be explained on a submicroscopic level. All that we observe about matter depends on atoms and the changes they undergo. Chemistry seeks to explain the submicroscopic events that lead to macroscopic observations. One way this can be done is by making a model, a visual representation of a submicroscopic event. **Figure 1-3** is such a model. The **problem-solving Lab** on the opposite page gives you practice interpreting a simple chemical model.

Branches in the field of chemistry Because there are so many types of matter, there are many areas of study in the field of chemistry. Chemistry is traditionally broken down into the five branches listed in **Table 1-1.**

Additional areas of chemisty include theoretical chemistry, which focuses on why and how chemicals interact, and environmental chemistry, which deals with the role chemicals play in the environment.

Careers Using Chemistry

Chemistry Teacher

Do you love chemistry? Would you like to help others love it—or at least understand it? If so, you might make an excellent chemistry teacher.

Chemistry teachers work in high schools and two-year and four-year colleges. They lecture, guide discussions, conduct experiments, supervise lab work, and lead field trips. High school teachers might also be asked to monitor study halls and serve on committees. College instructors might be required to do research and publish their findings.

Section 1.2 Assessment

6. Define matter.

7. Compare and contrast mass and weight.

8. Why does chemistry involve the study of the changes in the world at a submicroscopic level?

9. **Thinking Critically** Explain why a scientist must be cautious when a new chemical that has many potential uses is synthesized.

10. **Using Numbers** If your weight is 120 pounds and your mass is 54 kilograms, how would those values change if you were on the moon? The gravitational force on the moon is 1/6 the gravitational force on Earth.

Section 1.3

Scientific Methods

Objectives

- **Identify** the common steps of scientific methods.
- **Compare** and **contrast** types of data.
- **Compare** and **contrast** types of variables.
- **Describe** the difference between a theory and a scientific law.

Vocabulary

scientific method
qualitative data
quantitative data
hypothesis
experiment
independent variable
dependent variable
control
conclusion
model
theory
scientific law

Figure 1-8 shows students working together on an experiment in the laboratory. You know that each person in the group probably has a different idea about how to do the project and a different part of the project that interests him or her the most. Having many different ideas about how to solve a problem is one of the benefits of many people working together. Communicating ideas effectively to one another and combining individual contributions to form a solution can be difficulties encountered in group work.

A Systematic Approach

Scientists approach their work in a similar way. Each scientist tries to understand his or her world based on a personal point of view and individual creativity. Often, the work of many scientists is combined in order to gain new insight. It is helpful if all scientists use common procedures as they conduct their experiments.

A **scientific method** is a systematic approach used in scientific study, whether it is chemistry, biology, physics, or other sciences. It is an organized process used by scientists to do research, and it provides a method for scientists to verify the work of others. An overview of the typical steps of a scientific method is shown in **Figure 1-9.** The steps are not used as a checklist to be done in the same order each time. Therefore, all scientists must describe their methods when they publish their results. If other scientists cannot confirm the results after repeating the method, then doubt arises over the validity of the reported results.

Observation You make observations throughout your day in order to make decisions. Scientific study usually begins with simple observation. An observation is the act of gathering information. Quite often, the types of observations scientists first make are **qualitative data**—information that describes color, odor, shape, or some other physical characteristic. In general, anything that relates to the five senses is qualitative: how something looks, feels, sounds, tastes, or smells.

Figure 1-8

During your chemistry course, you will have opportunities to use scientific methods to perform investigations and solve problems.

CONTENTS

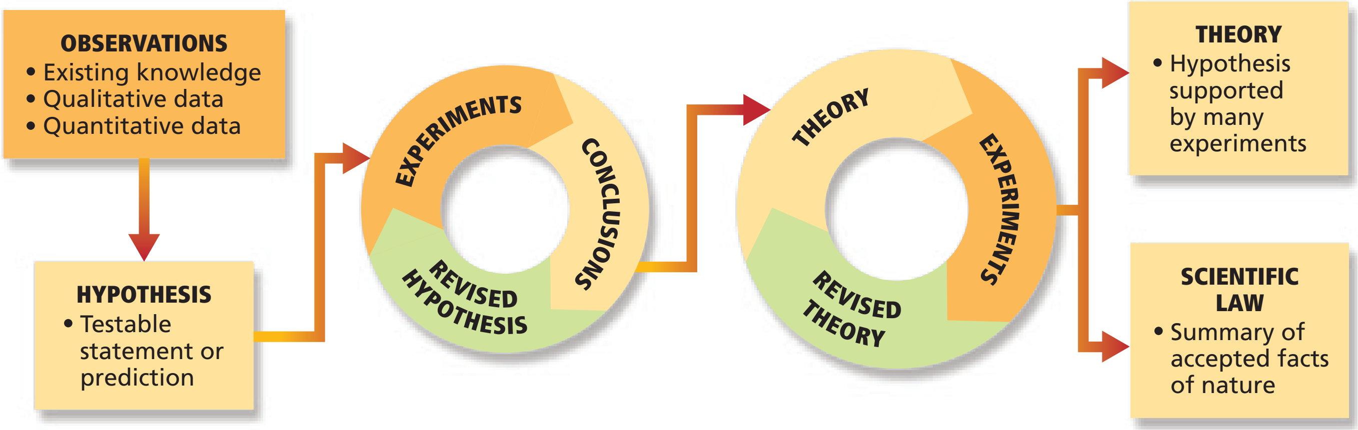


Figure 1-9

The steps in a scientific method are repeated until a hypothesis has been supported or discarded.

Chemists frequently gather another type of data. For example, they can measure temperature, pressure, volume, the quantity of a chemical formed, or how much of a chemical is used up in a reaction. This numerical information is called **quantitative data.** It tells you how much, how little, how big, how tall, or how fast. What kind of qualitative and quantitative data can you gather from **Figure 1-10?**

Hypothesis Let's return to the stories of two chemicals that you read about earlier. Even before quantitative data showed that ozone levels were decreasing in the stratosphere, scientists observed that CFCs were found there. Chemists Mario Molina and F. Sherwood Rowland were curious about how long CFCs could exist in the atmosphere.

Molina and Rowland examined the interactions that can occur among various chemicals in the troposphere. They determined that CFCs were stable there for long periods of time. But they also knew that CFCs drift up into the stratosphere. They formed a hypothesis that CFCs break down in the stratosphere due to interactions with ultraviolet light from the Sun. In addition, the calculations they made led them to hypothesize that a chlorine particle produced by this interaction would break down ozone.

A **hypothesis** is a tentative explanation for what has been observed. Molina and Rowland's hypothesis stated what they believed to be happening, even though there was no formal evidence at that point to support the statement.

Experiments A hypothesis means nothing unless there are data to support it. Thus, forming a hypothesis helps the scientist focus on the next step in a scientific method, the experiment. An **experiment** is a set of controlled observations that test the hypothesis. The scientist must carefully plan and set up one or more laboratory experiments in order to change and test one variable at a time. A variable is a quantity or condition that can have more than one value.

Suppose your chemistry teacher asks your class to use the materials shown in **Figure 1-11** to design an experiment in which to test the hypothesis that table salt dissolves faster in hot water than in water at room temperature (20°C).

Figure 1-10

Compare the qualitative and quantitative observations you can make from this photo with your classmates. Did you observe the same things?

Figure 1-11

These materials can be used to determine the effect of temperature on the rate at which table salt dissolves.

Because temperature is the variable that you plan to change, it is an **independent variable.** Your group determines that a given quantity of salt completely dissolves within 1 minute at 40°C but that the same quantity of salt dissolves only after 3 minutes at 20°C. Thus, temperature affects the rate at which the salt dissolves. This rate is called a **dependent variable** because its value changes in response to a change in the independent variable. Although your group can determine the way the independent variable changes, it has no control over the way the dependent variable changes.

What other factors could you vary in your experiment? Would the amount of salt you try to dissolve make a difference? The amount of water you use? Would stirring the mixture affect your results? The answer can be yes to all of these questions. You must plan your experiment so that these variables are the same at each temperature, or you will not be able to tell clearly what caused your results. In a well-planned experiment, the independent variable should be the only condition that affects the experiment's outcome. A constant is a factor that is not allowed to change during the experiment. The amount of salt, water, and stirring must be constant at each temperature.

In many experiments, it is valuable to have a **control,** that is, a standard for comparison. In the above experiment, the room-temperature water is the control. The rate of dissolving at 40°C is compared to the rate at 20°C. **Figure 1-12** shows a different type of control. A chemical indicator has been added to each of three test tubes. Acid is added to the middle test tube, and the indicator turns yellow. This test tube can be used as a control. Compare the other two test tubes with the control. Does either one contain acid?

Figure 1-12

The control test tube in the middle lets you make a visual comparison.

The interactions described between CFCs and ozone in Molina and Rowland's hypothesis take place high overhead. Many variables are involved. For example, there are different gases present in the stratosphere. Thus, it would be difficult to determine which gases, or possibly if all gases, are decreasing ozone levels. Winds, variations in ultraviolet light, and other factors could change the outcome of any experiment on any given day making comparisons difficult. Sometimes it is easier to simulate conditions in a laboratory where the variables can be more easily controlled.

An experiment may generate a large amount of data. These data must be carefully and systematically analyzed. Because the concept of data analysis is so important, you will learn more about it in the next chapter.

Conclusion Scientists take the data that have been analyzed and apply them to the hypothesis to form a conclusion. A **conclusion** is a judgment based on the information obtained. A hypothesis can never be proven. Therefore, to say

that the data support a hypothesis is to give only a tentative "thumbs up" to the idea that the hypothesis may be true. If further evidence does not support it, then the hypothesis must be discarded or modified. The majority of hypotheses are not supported, but the data may still yield new information.

Molina and Rowland formed a hypothesis about the stability of CFCs in the stratosphere. They gathered data that supported their hypothesis and developed a model in which the chlorine formed by the breakdown of CFCs would react over and over again with ozone. You must realize by now a **model** is a visual, verbal, and/or mathematical explanation of experimental data.

A model can be tested and used to make predictions. Molina and Rowland's model predicted the formation of chlorine and the depletion of ozone, as shown in **Figure 1-13.** Another research group found evidence of interactions between ozone and chlorine when taking measurements in the stratosphere, but they did not know the source of the chlorine. Molina and Rowland's model predicted a source of the chlorine. They came to the conclusion that ozone in the stratosphere could be destroyed by CFCs and that they had enough support for their hypothesis to publish their discovery.

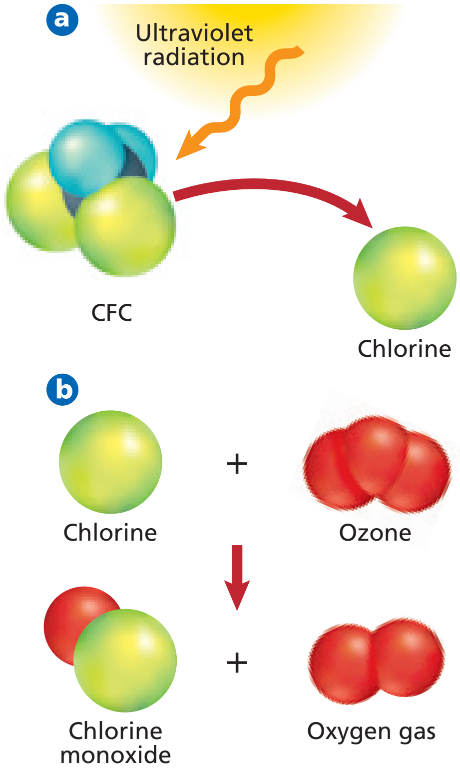


Figure 1-13

a Molina and Rowland's model predicted that ultraviolet radiation causes a chlorine particle to split off from a CFC.
b The chlorine particle then destroys the ozone by combining with it to form oxygen gas and chlorine monoxide.

Theory A **theory** is an explanation that has been supported by many, many experiments. You may have heard of Einstein's theory of relativity or the atomic theory. A theory states a broad principle of nature that has been supported over time. All theories are still subject to new experimental data and can be modified. Also, theories often lead to new conclusions.

A theory is considered successful if it can be used to make predictions that are true. In 1985, the announcement by the British Antarctic Survey that the amount of ozone in the stratosphere was decreasing lent Molina and Rowland's hypothesis—that chlorine from CFCs could destroy ozone—further support.

Scientific law Sometimes, many scientists come over and over again to the same conclusion about certain relationships in nature. They find no exceptions. For example, you know that no matter how many times skydivers leap from a plane, they always wind up back on Earth's surface. Sir Isaac Newton was so certain that an attractive force exists between all objects that he proposed his law of universal gravitation.

Newton's law is a **scientific law** and, as such, a relationship in nature that is supported by many experiments. It is up to scientists to develop further hypotheses and experimentation to explain why these relationships exist.

Section 1.3 Assessment

11. What is a scientific method? What are its steps?

12. You are asked to study the effect of temperature on the volume of a balloon. The balloon's size increases as it is warmed. What is the independent variable? Dependent variable? What factor is held constant? How would you construct a control?

13. Critique Molina and Rowland's hypothesis of ozone depletion as to its strengths and weaknesses.

14. Jacques Charles described the direct relationship between temperature and volume of all gases at constant pressure. Should this be called Charles's law or Charles's theory? Explain.

15. **Thinking Critically** Why must Molina and Rowland's data in the laboratory be supported by measurements taken in the stratosphere?

16. **Interpreting Data** A report in the media states that a specific diet will protect individuals from cancer. However, no data are reported to support this statement. Is this statement a hypothesis or a conclusion?

Section 1.4

Scientific Research

Objectives

- **Compare** and **contrast** pure research, applied research, and technology.
- **Apply** knowledge of laboratory safety.

Vocabulary

pure research
applied research
technology

Every day in the media, whether it's TV, newspapers, magazines, or the Internet, you are bombarded with the results of scientific investigations. Many deal with the environment, medicine, or health. As a consumer, you are asked to evaluate the results of scientific research and development. How do scientists use qualitative and quantitative data to solve different types of scientific problems?

Types of Scientific Investigations

Pure research seeks to gain knowledge for the sake of knowledge itself. Molina and Rowland conducted research on CFCs and their interactions with ozone as pure research, motivated by curiosity. No environmental evidence at the time indicated that there was a correlation to their model in the stratosphere. Their research only showed that CFCs could speed the breakdown of ozone in a laboratory setting.

When the ozone hole was reported in 1985, scientists had made measurements of CFC levels in the stratosphere that supported the hypothesis that CFCs could be responsible for the depletion of ozone. The pure research done only for the sake of knowledge became applied research. **Applied research** is research undertaken to solve a specific problem. Scientists continue to monitor the amount of CFCs in the atmosphere and the annual changes in the amount of ozone in the stratosphere. Applied research also is being done to find replacement chemicals for the CFCs that are now banned. Read the **Chemistry and Society** feature at the end of this chapter to learn about research into the human genome. What type of research does it describe?

Chance discoveries Sometimes, when a scientist plans research with a specific goal in mind, he or she will conduct experiments and reach a conclusion that is expected. Sometimes, however, the conclusion reached is far different from what was expected. Some truly wonderful discoveries in science have been made unexpectedly.

The discovery of nylon is one example. In 1928, E.I. DuPont de Nemours and Company appointed a young, 32-year-old chemist from Harvard, Wallace Carothers, as the director of its new research center. The goal was to create artificial fibers similar to cellulose and silk. In 1930, Julian Hill, a member of Carothers' team, dipped a hot glass rod in a mixture of solutions and unexpectedly pulled out long fibers such as the one shown in **Figure 1-14.** Carothers pursued the development of these fibers as a synthetic silk that could withstand high temperatures and eventually developed nylon in 1934. Nylon's first use was in a toothbrush with nylon bristles. During World War II, nylon was used as a replacement for silk in parachutes. Nylon is used extensively today in textiles and some kinds of plastics.

Students in the Laboratory

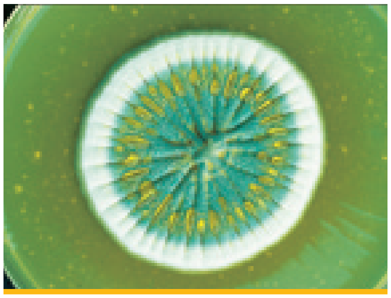
In your study of chemistry, you will learn many facts about matter. You also will do experiments in which you will be able to form and test hypotheses, gather and analyze data, and draw conclusions.

When you work in the chemistry laboratory, you are responsible for your safety and the safety of the people working nearby. **Table 1-2** on page 16 lists some safety rules that you must use as a guide each time you enter the lab.

Biology CONNECTION

Many discoveries in science are made quite unexpectedly. Alexander Fleming is famous for making two such discoveries. The first occurred in 1922, when nasal mucus accidentally dripped onto bacteria that he had been growing for research. Rather than throwing the culture plate away, he decided to observe it over the next several days. He found that the bacteria died. As a result, he discovered that lysozyme, a chemical in mucus and tears, helps protect the body from bacteria.

Six years later, in 1928, Fleming found that one of his plates of *Staphylococcus* bacteria had been contaminated by a greenish mold, later identified as *Penicillium.* He observed it carefully and saw a clear area around the mold where the bacteria had died. In this case, a chemical in the mold—penicillin—was responsible for killing the bacteria.



Chemists and all other scientists use these safety rules. Before you do the **miniLAB** at the bottom of this page or the **CHEMLAB** at the end of this chapter, read the procedures carefully. Which safety rules in **Table 1-2** apply?

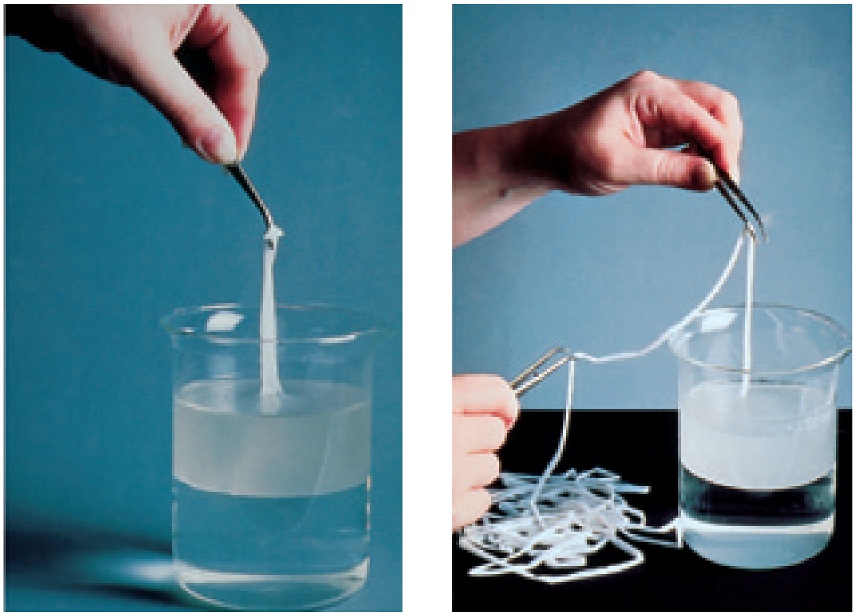


Figure 1-14

Strands of nylon can be pulled from the top layer of solutions. After its discovery, nylon was used mainly for war materials and was unavailable for home use until after World War II.

miniLAB

Developing Observation Skills

Observing and Inferring A chemist's ability to make careful and accurate observations is developed early. The observations often are used to make inferences. An inference is an explanation or interpretation of observations.

Materials petri dish (2), graduated cylinder, whole milk, water, vegetable oil, four different food colorings, toothpick (2), dishwashing detergent

Procedure

1. Add water to a petri dish to a height of 0.5 cm. Add 1 mL of vegetable oil.
2. Dip the end of a toothpick in liquid dishwashing detergent.
3. Touch the tip of the toothpick to the water at the center of the petri dish. Record your detailed observations.
4. Add whole milk to a second petri dish to a height of 0.5 cm.
5. Place one drop each of four different food colorings in four different locations on the surface of the milk, as shown in the photo. Do not put a drop of food coloring in the center.

6. Repeat steps 2 and 3.

Analysis

1. What did you observe in step 3?
2. What did you observe in step 6?
3. Oil, the fat in milk, and grease belong to a class of chemicals called lipids. What can you infer about the addition of detergent to dishwater?

Table 1-2

Safety in the Laboratory

1. Study your lab assignment **before** you come to the lab. If you have any questions, be sure to ask your teacher for help.
2. Do not perform experiments without your teacher's permission. **Never** work alone in the laboratory.
3. Use the table on the inside front cover of this textbook to understand the safety symbols. Read all **CAUTION** statements.
4. Safety goggles and a laboratory apron must be worn whenever you are in the lab. Gloves should be worn whenever you use chemicals that cause irritations or can be absorbed through the skin. Long hair must be tied back. See the photo below.
5. Do not wear contact lenses in the lab, even under goggles. Lenses can absorb vapors and are difficult to remove in case of an emergency.
6. Avoid wearing loose, draping clothing and dangling jewelry. Bare feet and sandals are not permitted in the lab.
7. Eating, drinking, and chewing gum are not allowed in the lab.
8. Know where to find and how to use the fire extinguisher, safety shower, fire blanket, and first-aid kit.

9. Report any accident, injury, incorrect procedure, or damaged equipment to your teacher.
10. If chemicals come in contact with your eyes or skin, flush the area immediately with large quantities of water. Immediately inform your teacher of the nature of the spill.
11. Handle all chemicals carefully. Check the labels of all bottles **before** removing the contents. Read the label three times:
    - Before you pick up the container.
    - When the container is in your hand.
    - When you put the bottle back.
12. Do not take reagent bottles to your work area unless instructed to do so. Use test tubes, paper, or beakers to obtain your chemicals. Take only small amounts. It is easier to get more than to dispose of excess.
13. Do not return unused chemicals to the stock bottle.
14. Do not insert droppers into reagent bottles. Pour a small amount of the chemical into a beaker.
15. **Never** taste any chemicals. **Never** draw any chemicals into a pipette with your mouth.
16. Keep combustible materials away from open flames.
17. Handle toxic and combustible gases only under the direction of your teacher. Use the fume hood when such materials are present.
18. When heating a substance in a test tube, be careful not to point the mouth of the test tube at another person or yourself. Never look down the mouth of a test tube.
19. Do not heat graduated cylinders, burettes, or pipettes with a laboratory burner.
20. Use caution and proper equipment when handling hot apparatus or glassware. Hot glass looks the same as cool glass.
21. Dispose of broken glass, unused chemicals, and products of reactions only as directed by your teacher.
22. Know the correct procedure for preparing acid solutions. **Always** add the acid slowly to the water.
23. Keep the balance area clean. Never place chemicals directly on the pan of a balance.
24. After completing an experiment, clean and put away your equipment. Clean your work area. Make sure the gas and water are turned off. Wash your hands with soap and water before you leave the lab.

CONTENTS

Figure 1-15

Nuclear power and artificial limbs and joints are just a few of the technological advances that have improved human life.

Benefits of Chemistry

It is easy to understand the purpose of applied research because it addresses a specific problem. It also is easier to see its immediate benefit. Yet, when a sudden, unexpected event occurs in the world, whether it's the ozone hole or the AIDS epidemic, the first line of defense is to look at the pure research that has already been conducted.

The products that we use to make our lives easier and more comfortable are the result of technological applications of pure and applied research. **Technology** is the practical use of scientific information. It is concerned with making improvements in human life and the world around us. As **Figure 1-15** shows, advances in technology can benefit us in many ways.

Section 1.4 Assessment

17. Compare and contrast pure research and applied research.

18. What is technology? Is technology a product of pure research or applied research? Explain.

19. Explain why it is important to read each **CHEMLAB** and **miniLAB** before you come to class.

20. **Thinking Critically** Explain the reason behind each of the following.

- **a.** Wear goggles and an apron in the lab even if you are only an observer.
- **b.** Report all accidents to your teacher.
- **c.** Do not return unused chemicals to the stock bottle.

21. **Interpreting Scientific Diagrams** What safety precautions should you take when you see the following safety symbols?

CONTENTS

CHEMLAB 1

The Rubber Band Stretch

Galileo Galilei (1564–1642) was an Italian philosopher, astronomer, and mathematician. Galileo pioneered the use of a systematic method of observation, experimentation, and analysis as a way to discover facts about nature. Modern science has its roots in Galileo's 17th-century work on the art of experimentation. This chapter introduced you to how scientists approach their work. In this **CHEMLAB**, you will have a chance to design a scientific method to study something you have observed many times before—the stretching of a rubber band.

Problem

What happens when you heat a stretched rubber band?

Objectives

- **Observe** the properties of a stretched and a relaxed rubber band.
- **Form a hypothesis** about the effect of heat on a stretched rubber band.
- **Design** an experiment to test your hypothesis.
- **Collect** and **analyze** data.
- **Draw conclusions** based on your analysis.

Materials

large rubber band
500-g mass
ring stand
clamp
hair dryer
meter stick or ruler

Safety Precautions

- **Frequently observe the rubber band for any splits. Discard if rubber band is defective.**
- **The hair dryer can become hot, so handle it with care.**

Pre-Lab

1. Heat is the transfer of energy from a warmer object to a cooler object. If an object feels warm to your finger, your finger is cooler than the object and energy is being transferred from the object to your finger. In what direction does the energy flow if an object feels cooler to you?
2. Your forehead is very sensitive to hot and cold. How can you use this fact to detect whether an object is giving off or absorbing heat?
3. Read the entire **CHEMLAB.** It is important to know exactly what you are going to do during all chemistry experiments so you can use your laboratory time efficiently and safely. What is the problem that this experiment is going to explore?
4. What typical steps in a scientific method will you use to explore the problem? Write down the procedure that you will use in each experiment that you design. Be sure to include all safety precautions.
5. You will need to record the data that you collect during each experiment. Prepare data tables that are similar to the one below.

Rubber Band Data

Experiment #	Observations
Trial 1	
Trial 2	
Trial 3	
Trial 4	

Procedure

1. Obtain one large rubber band. Examine the rubber band for any splits or cracks. If you find any defects, discard it and obtain a new one.
2. Record detailed observations of the unstretched rubber band.
3. Design your first experiment to observe whether heat is given off or absorbed by a rubber band as it is stretched. Have your instructor approve your plan.
4. Do repeated trials of your experiment until you are sure of the results. **CAUTION:** *Do not bring the rubber band near your face unless you are wearing goggles.*
5. Design a second experiment to observe whether heat is given off or absorbed by a rubber band as it contracts after being stretched. Have your instructor approve your plan.
6. Do repeated trials of your experiment until you are sure of the results.
7. Use your observations in steps 2, 4, and 6 to form a hypothesis and make a prediction about what will happen to a stretched rubber band when it is heated.
8. Use the remaining items in the list of materials to design a third experiment to test what happens to a stretched rubber band as it is heated. Have your instructor approve your plan. Be sure to record all observations before, during, and after heating.

Cleanup and Disposal

1. Return the rubber band to your instructor to be reused by other classes.
2. Allow the hair dryer to cool before putting it away.

Analyze and Conclude

1. **Observing and Inferring** What results did you observe in step 4 of the procedure? Was energy gained or lost by the rubber band? By your forehead? Explain.
2. **Observing and Inferring** What results did you observe in step 6 of the procedure? Was energy gained or lost by the rubber band? By your forehead? Explain.
3. **Applying** Many substances expand when they are heated. Did the rubber band behave in the same way? How do you know?
4. **Drawing a Conclusion** Did the result of heating the stretched rubber band in step 8 confirm or refute your hypothesis? Explain.
5. **Making Predictions** What would happen if you applied ice to the stretched rubber band?
6. **Error Analysis** Compare your results and conclusion with those of your classmates. What were your independent and dependent variables? Did you use a control? Did all of the lab teams measure the same variables? Were the data that you collected qualitative or quantitative? Does this make a difference when reporting your data to others? Do your results agree? Why or why not?

Real-World Chemistry

1. When you put ice in a glass so that the ice rises higher than the rim, water does not overflow the glass when the ice melts. Explain.
2. Why do you think temperature extremes must be taken into account when bridges and highways are designed?

CHEMISTRY and Society

The Human Genome Project

From eye and skin color to the potential for developing disease, humans display remarkable and endless variety. Much of this variety is controlled by the human genome: the complete “instruction manual” found in the nucleus of all cells that is used to define a specific organism. Decoding and understanding these instructions is the goal of the Human Genome Project (HGP). The United States Department of Energy and the National Institutes of Health coordinated the project that began in 1990. Private industry also is involved. The HGP fosters cooperation as well as competition among researchers in a project that could hasten advances in treatment of human genetic conditions such as cancer and heart disease.

A common goal, a common approach

The year 2003 marks the fiftieth anniversary of Watson and Crick’s discovery of the structure of DNA. Chemicals called nitrogen bases connect the twisted strands that make up DNA. There are roughly three billion pairs of these bases in the human genome. Determining the sequence, or order, in which these base pairs occur was one common goal of researchers working on the HGP. Biologists, chemists, physicists, computer specialists, and engineers across the country approach the task from different angles. Use of scientific methods was the unifying theme in all of this work.

Prior to the HGP, researchers around the world used scientific methods to work independently on the mammoth task of decoding the human genome. Without coordination, however, the data they collected were analyzed and stored using different databases and were shared only through scientific journals and conferences. Those working on the HGP used common methods for gathering and analyzing data. Results were shared through databases that are rapidly available through the World Wide Web, enhancing communication, cooperation, and the flow of information. Because of this cooperation, a rough map of the human genome was completed several years ahead of schedule. Much work still remains to be done, however, and results will have to be shared by researchers working on the project.

Looking toward the future

The Human Genome Project is spurring medical advances. But this powerful knowledge also raises important issues. For example, if a person’s genome map shows a predisposition for a certain illness, should an employer or insurance company be informed? While the HGP is opening exciting doors, the associated ethical, legal, and societal issues must be acknowledged and addressed.

Investigating the Issue

1. **Communicating Ideas** Research some of the ethical, legal, and societal issues being raised by genome research. Write a brief essay giving your opinion about how one or more of these issues could be addressed.

2. **Debating the Issue** The race to sequence the human genome took place in both the public and private sectors. Find information about several companies that worked independently on genome research. Is it ethical for them to sell this information, or should it be freely shared with others?

CHEMISTRY Online CLICK HERE

Visit the Chemistry Web site at **science.glencoe.com** to find links to more information about the Human Genome Project.

CHAPTER 1 STUDY GUIDE

Summary

1.1 The Stories of Two Chemicals

- The building blocks of the matter in the universe formed in the stars.
- A chemical is any substance that has a definite composition.
- Ozone is a chemical that forms a protective layer in Earth's atmosphere.
- Ozone is formed in the stratosphere when ultraviolet radiation from the Sun strikes oxygen gas.
- Thinning of the ozone layer over Antarctica is called the ozone hole.
- CFCs are synthetic chemicals made of chlorine, fluorine, and carbon.
- CFCs were used as refrigerants and as propellants in aerosol cans.
- CFCs can drift into the stratosphere.

1.2 Chemistry and Matter

- Chemistry is the study of matter and the changes that it undergoes.
- Matter is anything that has mass and takes up space.
- Mass is a measure of the amount of matter.
- Weight is a measure not only of an amount of matter but also the effect of Earth's gravitational pull on that matter.
- There are five traditional branches of chemistry: organic chemistry, inorganic chemistry, physical chemistry, analytical chemistry, and biochemistry.
- Macroscopic observations of matter reflect the actions of atoms on a submicroscopic scale.

1.3 Scientific Methods

- Typical steps of a scientific method include observation, hypothesis, experiments, data analysis, and conclusion.
- Qualitative data describe an observation; quantitative data use numbers.
- An independent variable is a variable that you change in an experiment.
- A dependant variable changes in response to a change in the independent variable.
- A theory is a hypothesis that has been supported by many experiments.
- A scientific law describes relationships in nature.

1.4 Scientific Research

- Scientific methods can be used in pure research for the sake of knowledge, or in applied research to solve a specific problem.
- Laboratory safety is the responsibility of anyone who conducts an experiment.
- Many of the conveniences we enjoy today are technological applications of chemistry.

Vocabulary

- applied research (p. 14)
- chemistry (p. 7)
- conclusion (p. 12)
- control (p. 12)
- dependent variable (p. 12)
- experiment (p. 11)
- hypothesis (p. 11)
- independent variable (p. 12)
- mass (p. 8)
- matter (p. 8)
- model (p. 13)
- pure research (p. 14)
- qualitative data (p. 10)
- quantitative data (p. 11)
- scientific law (p. 13)
- scientific method (p. 10)
- technology (p. 17)
- theory (p. 13)
- weight (p. 8)

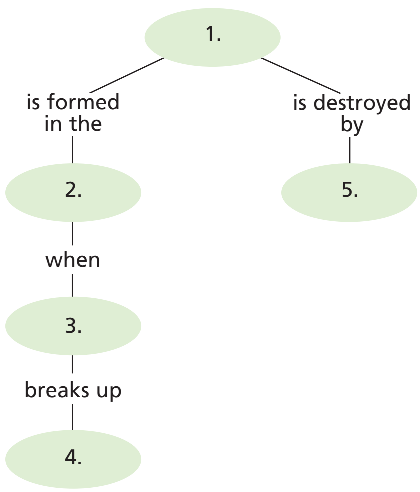
CHEMISTRY Online

CLICK HERE

Go to the Chemistry Web site at **science.glencoe.com** *or use the* **Chemistry CD-ROM** *for additional Chapter 1 Assessment.*

Concept Mapping

22. Complete the concept map using the following terms: stratosphere, oxygen gas, CFCs, ozone, ultraviolet radiation.



Mastering Concepts

23. What is a chemical? (1.1)

24. Where is ozone located in Earth's atmosphere? (1.1)

25. Explain the balance between oxygen and ozone in the stratosphere. Why is it important? (1.1)

26. What were common uses of CFCs? (1.1)

27. What is chemistry? (1.2)

28. Why is chemistry called the central science? (1.2)

29. Which measurement depends on gravitational force—mass or weight? Explain. (1.2)

30. Which branch of chemistry studies the composition of substances? Environmental impact of chemicals? (1.2)

31. How does qualitative data differ from quantitative data? Give examples of each. (1.3)

32. What is the function of a control in an experiment? (1.3)

33. What is the difference between a hypothesis, a theory, and a law? (1.3)

34. In the study of water, what questions might be asked in pure research? Applied research? Technology? (1.4)

Thinking Critically

35. Compare and Contrast Why is CFC depletion of the ozone layer a theory and not a scientific law?

36. Classifying CFCs break down to form chemicals that react with ozone. Is this a macroscopic or a microscopic observation?

37. Communicating Ideas Scientists often learn as much from an incorrect hypothesis as they do from one that is correct. Explain.

38. Designing an Experiment How would you design an experiment to evaluate the effectiveness of a "new and improved" chemical fertilizer on bean plants? Be sure to describe your hypothesis, procedure, variables, and control.

39. Inferring A newscaster reports, "The air quality today is poor. Visibility is only a quarter mile. Pollutants in the air are expected to rise above 0.085 parts per million (ppm) in the next eight hour average. Spend as little time outside today as possible if you suffer from asthma or other breathing problems." Which of these statements are qualitative and which are quantitative?

40. Comparing and Contrasting Match each of the following research topics with the branch of chemistry that would study it: water pollution, the digestion of food in the human body, the composition of a new textile fiber, metals to make new coins, a treatment for AIDS.

Writing in Chemistry

41. Based on your beginning knowledge of chemistry, describe the research into depletion of the ozone layer by CFCs in a timeline.

42. Learn about the most recent measures taken by countries around the world to reduce CFCs in the atmosphere since the Montreal Protocol. Write a short report describing the Montreal Protocol and more recent environmental measures to reduce CFCs.

43. Name a technological application of chemistry that you use everyday. Prepare a booklet about its discovery and development.

Cumulative Review

In chapters 2 through 26, this heading will be followed by questions that review your understanding of previous chapters.

CONTENTS

Use these questions and the test-taking tip to prepare for your standardized test.

1. Matter is defined as anything that _____.

a. exists in nature
b. is solid to the touch
c. is found in the universe
d. has mass and takes up space

2. Mass is preferred as a measurement over weight for all of the following reasons EXCEPT _____.
a. it has the same value everywhere on Earth
b. it is independent of gravitational forces
c. it becomes less in outer space, farther from Earth
d. it is a constant measure of the amount of matter

3. Which of the following is an example of pure research?

a. creating synthetic elements to study their properties
b. producing heat-resistant plastics for use in household ovens
c. finding ways to slow down the rusting of iron ships
d. searching for fuels other than gasoline to power cars

4. When working with chemicals in the laboratory, which of the following is something you should NOT do?

a. Read the label of chemical bottles before using their contents.
b. Pour any unused chemicals back into their original bottles.
c. Use lots of water to wash skin that has been splashed with chemicals.
d. Take only as much as you need of shared chemicals.

Interpreting Tables and Graphs Use the table and graph to answer questions 5–7.

5. What must be a constant during the experiment?

a. temperature
b. mass of CO_2 dissolved in each sample
c. amount of beverage in each sample
d. independent variable

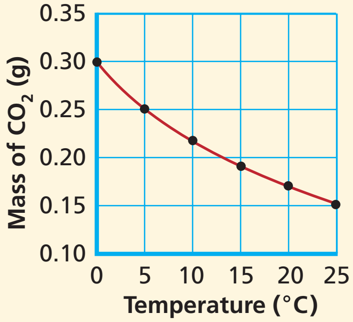
6. Assuming that all of the experimental data are correct, what is a reasonable conclusion for this experiment?

a. Greater amounts of CO_2 dissolve in a liquid at lower temperatures.
b. The different samples of beverage contained the same amount of CO_2 at each temperature.
c. The relationship between temperature and solubility seen with solids is the same as the one seen with CO_2.
d. CO_2 dissolves better in a liquid at higher temperatures.

Page From a Student's Laboratory Notebook

Step	Notes
Observation	Carbonated beverages taste fizzier (more gassy) when they are warm than when they are cold. (Carbonated beverages are fizzy because they contain dissolved carbon dioxide gas.)
Hypothesis	At higher temperatures, greater amounts of carbon dioxide gas will dissolve in a liquid. This is the same relationship between temperature and solubility seen with solids.
Experiment	Measure the mass of carbon dioxide (CO_2) in different samples of the same carbonated beverage at different temperatures.
Data Analysis	See graph below.
Conclusion	?

Mass of CO_2 Dissolved in a Carbonated Beverage



7. The scientific method used by this student showed that _____.

a. the hypothesis is supported by the experimental data
b. the observation accurately describes what occurs in nature
c. the experiment is poorly planned
d. the hypothesis should be thrown out

THE PRINCETON REVIEW **TEST-TAKING TIP**

More Than One Graphic If a test question has more than one table, graph, diagram, or drawing with it, use them all. If you answer based on just one graphic, you've probably missed an important piece of information. For questions 5-7 above, make sure that you accurately analyzed both graphics before answering the questions.